# Internet-Enabled Interactive Multimedia Asthma Education Program: A Randomized Trial

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**ABSTRACT.** *Objective.* **To determine whether health outcomes of children who have asthma can be improved through the use of an Internet-enabled interactive multimedia asthma education program.**

*Methods.* **Two hundred twenty-eight children with asthma visiting a pediatric pulmonary clinic were randomly assigned to control and intervention groups. Children and caregivers in both groups received traditional patient education based on the National Asthma Education and Prevention Program. Intervention group participants received additional self-management education through the Interactive Multimedia Program for Asthma Control and Tracking. Pediatric Asthma Care Knowledge Survey, Pediatric Asthma Caregiver's Quality of Life Questionnaire, asthma symptom history, spirometry, and health services utilization data were collected at the initial visit and at 3 and 12 months.**

*Results.* **Interactive Multimedia Program for Asthma Control and Tracking significantly increased asthma knowledge of children and caregivers, decreased asthma symptom days (81 vs 51 per year), and decreased number of emergency department visits (1.93 vs 0.62 per year) among the intervention group participants. The intervention group children were also using a significantly lower average daily dose of inhaled corticosteroids (434 vs 754 μg [beclomethasone equivalents]) at visit 3. Asthma knowledge of all 7- to 17-year-old children correlated with fewer urgent physician visits ($r = 0.37$) and less frequent use of quick-relief medicines ($r = 0.30$).**

*Conclusions.* **Supplementing conventional asthma care with interactive multimedia education can significantly improve asthma knowledge and reduce the burden of childhood asthma.** *Pediatrics* **2003;111:503–510;** ***asthma, education, pediatric, self-management, multimedia, interactive, computer, Internet.***

ABBREVIATIONS. IMPACT, Interactive Multimedia Program for Asthma Control and Tracking; QOL, quality of life; ICS, inhaled corticosteroids.

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Asthma affects 26 million people in the United States, 8.6 million of whom are children.[1] It is estimated that 5% to 10% of children have asthma, making it the most common chronic disease seen in the pediatric population.[2] Children with asthma have a higher number of school absences, nighttime awakenings, missed school days, and missed work days by parents than nonasthmatic children.[3,4] In addition, asthmatic children incur significantly more health care-related expenses than other children, with a spending of over 3 billion dollars per year.[5,6]

According to the Centers for Disease Control and Prevention, National Center for Health Statistics, in 1998, 3.8 million 0- to 17-year-old children had an asthma episode or attack, with males more likely to have had an asthma episode or attack (59 per 1000 males vs 41 per 1000 females).[7] In the same year, there were 5.8 million outpatient visits for asthma, over 867 000 emergency department visits, and over 89 000 hospitalizations by children aged 0 to 17 years, with highest numbers occurring among 0- to 4-year-old children.[7] Multiple factors are responsible for excessive asthma morbidity including undertreatment,[8] lack of adherence to recommended treatment regimens,[9] inadequate antiinflammatory treatment usage, environmental triggers, and inadequate patient/caregiver education.[10]

The Expert Guidelines for the Diagnosis and Management of Asthma[11] advocate patient education as a critical component of quality asthma care. Yet, significant health system barriers exist that make it difficult to provide effective education in clinical settings.[12] Major challenges include allocation of adequate staff time for patient education, selection of instructional approaches that can be sustained across various settings of care (clinic, home, and school), adjustment of content to meet individual patient's needs, assessment of learners' comprehension, provision of appropriate remedial education, documentation of instructional activities and educational outcomes, and conservation of patients' time and resources. Other major constraints are high costs and lack of reimbursement for patient education. These barriers ultimately result in the failure of the health care system to provide adequate asthma education.[12]

Interactive patient education has been shown to be effective in the management of several diseases.[13–15] Multimedia instructional programs can complement one-on-one education by a health professional; how-

ever, this approach has been rarely used, attributable primarily to the high cost and technical complexity of free-standing tutorial systems. The Internet constitutes a widely available and affordable multimedia instructional medium that can help overcome some of the barriers to delivering effective patient education. Internet-enabled programs that use a secure server can deliver, customize, and record tutorial sessions, as well as provide the patient an opportunity to communicate with their health care team.[16] Although a number of computer-based asthma education programs have been developed and evaluated, there has been no report to our knowledge of an Internet-enabled asthma education program for children and caregivers that has been evaluated in a randomized, controlled trial.[17–20]

The purpose of this study was to determine whether the addition of an interactive multimedia asthma education program (based on the National Asthma Education and Prevention Program)[11] to a traditional clinic-based patient education program would improve children's and caregivers' knowledge and health status and decrease use of health care resources.

## METHODS

A randomized, controlled study was designed to determine: 1) whether addition of an interactive multimedia asthma education program significantly increases asthma knowledge of children and caregivers; 2) whether asthma knowledge is significantly related to the disease outcomes and health care resource utilization by asthmatic children; and 3) whether there is a significant difference between the intervention group and the control group in disease outcomes and use of health care resources among asthmatic children.

### Population and Site

The population for this study consisted of children under 18 years old who have asthma and their caregivers who were followed at the Pediatric Pulmonary and Allergy Clinic of the University of Missouri-Columbia Health Care between February 1999 and October 2000. The clinic provides care to >1000 children who are referred by their primary care physicians for asthma and who come from a 22 county service area. The study was approved by the Institutional Review Board of the University of Missouri-Columbia Health Sciences Center.

### Eligibility and Sample

Patients and their caregivers were eligible for the study if a child had a confirmed diagnosis of asthma[11] and was under 18 years old. Children with a diagnosis of cystic fibrosis, bronchopulmonary dysplasia, or other chronic lung diseases were not eligible. A sample size calculation determined that 100 children in each of the 2 groups would have a power of 94% for detecting an effect size of 0.5 (the difference in the group means divided by the common standard deviation) in any of the variables studied. All children meeting the eligibility criteria were invited to participate, and no children were excluded based on the severity of asthma.

### Randomization and Blinding

All eligible pediatric patients and their caregivers were given the opportunity to participate in the study and were enrolled if they signed an informed consent form. They were then randomly assigned to 1 of 2 groups, the traditional asthma education group or the interactive multimedia education group. The pulmonologists in the Pediatric Pulmonary and Allergy Clinic caring for the participant children were blind to which patients were enrolled in the study and to what group they were assigned.

### Instruments and Data Collection

During the initial visit, baseline demographic data were collected for both the child and the caregiver. For every child enrolled in the study a caregiver completed a Caregiver Enrollment Form. For children 6 years and younger, caregivers completed additional instruments: Child Enrollment Form, Asthma Summary Since Last Visit, Pediatric Asthma Care Knowledge Survey, and Pediatric Asthma Caregiver's Quality of Life Questionnaire.[21] The knowledge questionnaire consists of 50 questions on basic asthma concepts and 10 questions on dilemmas dealing with real-life asthma scenarios. Children 7 years of age and older completed the Child Enrollment Form, Asthma Summary Since Last Visit, Pediatric Asthma Care Knowledge Survey and Pediatric Asthma Quality of Life Questionnaire.[22] Data were collected at 2 subsequent visits scheduled at ~3 and 12 months, before being seen and participating in educational activities. Intervention group children and caregivers also completed a Program Evaluation form during the last visit.

### The Control Group—Printed and Verbal Asthma Education

All control group participants received asthma education as part of the usual care, including verbal and printed information on the disease and concepts related to its control. A total of 26 instructional sheets in the Caring for Kids With Asthma series were available to the clinical team to help families understand asthma, selected devices, medications, and environmental factors. These illustrated information sheets were written at a second-grade reading level. Each family received a basic set of 8 and 4 or more additional sheets describing specific aspects of the child's plan of care, such as the particular medications or devices needed. Education and training were provided to all families by a nurse practitioner. This involved approximately 1.5 hours of direct patient contact over the first 3 visits after initial diagnosis and an additional 15 minutes per visit when the plan of care changed significantly. During clinic visits each child or caregiver took part in one-on-one training to ensure correct use of devices and medications. All families received an individualized, computer-generated asthma action plan with detailed instructions for daily self-management, as well as guidelines for handling exacerbations and emergencies.[23] Copies of the asthma action plan were also provided to the day care or school, the primary care physician, and the hospital chart.

### The Intervention Group—Internet-Enabled, Interactive Multimedia Asthma Education

In addition to receiving conventional patient education, children and families in the intervention group used Interactive Multimedia Program for Asthma Control and Tracking (IMPACT) during routine office visits. The IMPACT Asthma Kids CD was designed and produced by the Advanced Technology Center and the Children's Hospital at the University of Missouri-Columbia. It consists of vignettes covering the basic pathophysiology of asthma, environmental triggers, quick-relief and control medicines, and strategies to control and manage asthma. The program incorporates principles of self-management in an interactive format consisting of animated lessons, each averaging a minute in length. Ten of the lessons present real-life scenarios and require decisions about alternative behaviors that would likely affect asthma. Other lessons involve activities in which children learn to more accurately describe their symptoms and medication use.

Content for IMPACT was initially developed in illustrated, storyboard format by a multidisciplinary team that drew heavily from expert asthma guidelines. In addition, IMPACT was expressly designed to satisfy specific theoretical constructs pertaining to self-management of asthma by school-aged children. To be included in the final multimedia version, each concept had to logically relate to a child becoming more vigilant for signs of asthma and threats in the environment or to a child acting effectively to abate asthma. Application of multimedia techniques to a clear set of behavioral objectives was accomplished through the use of specific graphic templates for each of 4 types of interactive vignettes. Each template was designed to illustrate concepts, test comprehension and reinforce learning, develop decision-making skills, or improve a child's ability to communicate their asthma signs and symptoms to others. Several easily recognizable icons

were developed and used for consistency. Finally, IMPACT used the Internet and a Web-based server to respond to individual learner needs.

The program is password-protected, and its technical features are implemented through a secure database on a server that is accessed over the Internet. The program was only made available to children and families during clinic visits. This decision was made in view of the fact that making the program available from home would add an access variable that would introduce bias in comparison of the groups.

Content in both the printed educational materials and IMPACT was based on the Asthma Expert Guidelines.[11] The program tracks educational progress of individual children and generates standardized reports to help children, families and schools record current symptom level and medication use. The program reports the percentage of the 44 lessons mastered, as defined by a user having correctly answered questions after viewing a vignette. After entering an incorrect answer a user is immediately presented with the correct answer and an explanation of the concepts. The program can be completed in approximately 1 hour 20 minutes, although the actual time may vary depending on the reading level and comprehension of the user.

A computer was available in each consultation room and in a waiting area within the clinic. Program use occurred during regular appointments as clinic staff entered and left the room and no additional encounters were scheduled for computer learning. At each tutorial session, IMPACT first presented for review lessons previously viewed for which incorrect answers were entered, followed by new content, progressing in a linear fashion through the 44 lessons. To minimize the risk that critical concepts would be forgotten between visits, the program automatically reviewed any lesson that had aged >6 months. Consistent with a self-management approach, IMPACT interspersed several types of lessons, including traditional instructional vignettes, decision-making scenarios, and exercises to improve the child's ability to report their symptoms and medication use. If the child was in the 0- to 6-year age group, the parent used the program and their knowledge was assessed. Children 7 to 17 years used the program while their parents observed. In this group both the child's and parent's knowledge were measured. Participants used the program during every visit.

### Analysis

The data were analyzed using SAS statistical software (SAS Institute Inc, Cary, NC) on an intention-to-treat basis. To analyze the data, both control and intervention groups were subdivided into 3 subgroups—caregivers of children 0 to 6 years old, caregivers of the children 7 to 17 years old, and children 7 to 17 years old.

## RESULTS

The original study sample consisted of 246 children and their caregivers, which were randomized into the control group ($n = 127$) and the intervention group ($n = 119$). Of the 249 eligible families who were invited to participate into the study, 3 families declined to participate, giving "too busy," "not interested," and "too much hassle" as the reasons for their nonparticipation. Seventeen subjects, 6 from the control group and 11 from the intervention group, were excluded either at the request of the participants themselves or for lack of data. One intervention group child was excluded from analysis because of suspected diagnosis of Munchausen by proxy, leaving a final sample of 228 children. The demographic data for children are summarized in Table 1. Of the 228 caregivers, 88% were females, 90% white, 6% African American, and 4% of other ethnic origins. Fifty-four percent of caregivers had a high school education, 37% had 1 or more years of college, and the remaining 9% had junior high school education or less. Results of Wilcoxon rank sum tests evaluating asthma-related outcome variables (all $P$ values $>.05$) indicated that control and intervention groups were comparable in asthma severity at baseline.

### Knowledge

Asthma knowledge scores between visits 1 and 3 for the 3 subgroups in both control and intervention groups were analyzed (Table 2). Results of the signed rank sum tests showed that all 3 subgroups for both control and intervention showed a significant increase in knowledge ($P < .05$; Table 3). To determine whether there was a significant difference between groups, control and intervention groups were compared using the Cochran-Mantel-Haenszel statistic, controlling for the baseline knowledge scores through stratified analysis. Knowledge improvement between visits 1 and 3 was significantly greater among all 3 intervention groups: caregivers of children 0 to 6 years old with a $\chi^2 = 6.921$, $P < .01$; caregivers of children 7 to 17 years old with a $\chi^2 = 7.2084$, $P < .01$; and the intervention group of 7- to 17-year-old children with a $\chi^2 = 11.706$, $P < .01$.

### Relationship Between Knowledge and Health Outcomes, Resource Utilization

Assessment of the relationship between asthma knowledge of all 7- to 17-year-old children and of

**TABLE 1.** Demographic Data—Children

| | Control ($n = 121$) | | Intervention ($n = 107$) | | Total | % |
|---|---|---|---|---|---|---|
| | 0–6 Years | 7–17 Years | 0–6 Years | 7–17 Years | | |
| Gender | | | | | | |
| Male | 46 | 30 | 44 | 28 | 148 | 65% |
| Female | 23 | 22 | 18 | 17 | 80 | 35% |
| Ethnicity | | | | | | |
| White | 57 | 45 | 52 | 41 | 195 | 86% |
| African American | 7 | 2 | 9 | 1 | 19 | 8% |
| American Indian | 5 | 2 | 1 | 1 | 9 | 4% |
| Other or unknown | 0 | 3 | 0 | 2 | 5 | 2% |
| Education level | | | | | | |
| Preschool/none | 58 | * | 48 | * | 106 | 46% |
| Kindergarten | 6 | * | 12 | * | 18 | 8% |
| Elementary | 5 | 22 | 2 | 21 | 50 | 22% |
| Junior high school | * | 24 | * | 19 | 47 | 19% |
| High school | * | 6 | * | 5 | 11 | 5% |

* Not applicable to children 0 to 6 years old since only caregivers filled out the questionnaires.

**TABLE 2.** Knowledge Scores—Caregivers and Children

| | Visit 1 | | Visit 2 | | Visit 3 | |
|---|---|---|---|---|---|---|
| | *n* | Mean (SD) | *n* | Mean (SD) | *n* | Mean (SD) |
| Control | | | | | | |
| Caregivers children 0–6 y* | 69 | 48.41 (6.64) | 45 | 51.27 (5.57) | 23 | 52.30 (5.55) |
| Caregivers children 7–17 y† | 52 | 49.57 (4.75) | 43 | 52.02 (3.89) | 28 | 51.70 (4.42) |
| Children 7–17 y‡ | 52 | 43.44 (6.10) | 43 | 45.95 (5.67) | 28 | 47.51 (5.95) |
| Intervention | | | | | | |
| Caregivers children 0–6 y* | 62 | 47.94 (5.24) | 40 | 50.40 (6.24) | 24 | 55.68 (4.28) |
| Caregivers children 7–17 y† | 45 | 49.95 (5.59) | 35 | 51.66 (5.07) | 26 | 55.38 (4.16) |
| Children 7–17 y‡ | 45 | 43.11 (6.76) | 35 | 49.67 (5.98) | 25 | 53.12 (5.56) |

SD indicates standard deviation.
In $\chi^2$ comparison between control and intervention groups:
* $P < .01$.
† $P < .01$.
‡ $P < .001$.

**TABLE 3.** Changes in Knowledge, Health Outcomes, Resource Utilization Between Visits 1 and 3

| | *n* | Mean (SD) | Median | 95% CI Median | *P* Value |
|---|---|---|---|---|---|
| Control | | | | | |
| Days with asthma symptoms | 44 | −44.17 (98.19) | 17.16 | 8.40, 63.15 | .0010 |
| Days of quick relief medicine | 45 | −73.00 (133.23) | 19.35 | 8.40, 100.38 | .0004 |
| Days of activity limitation | 45 | −15.33 (52.20) | 0.00 | 0.00, 12.05 | .0951 |
| Nights of sleep disturbance | 45 | −38.69 (94.17) | 12.05 | 2.56, 37.60 | <.0001 |
| Urgent visits to physician | 45 | −5.48 (11.32) | 0.00 | 0.0, 06.21 | <.0001 |
| Emergency room visits | 45 | −1.46 (3.65) | 0.00 | 0.0, 0.0 | .0219 |
| Hospitalizations | 45 | −0.73 (3.29) | 0.00 | 0.0, 0.0 | .0313 |
| Days of stay in hospital | 45 | −3.65 (13.51) | 0.00 | 0.0, 0.0 | .0781 |
| School days missed | 43 | −1.63 (16.74) | 0.00 | 0.0, 0.0 | .1479 |
| Inhaled steroids | 49 | 172.65 (664.93) | 0.00 | −32.00, 0.0 | .0364 |
| Knowledge caregivers (0–6) | 23 | 2.52 (6.71) | 5.00 | −0.38, 5.42 | .0293 |
| Knowledge caregivers (7–17) | 28 | 2.38 (4.38) | 2.50 | 0.0, 4.00 | .0079 |
| Knowledge children (7–17) | 27 | 4.44 (5.49) | 4.00 | 2.00, 7.00 | .0001 |
| Intervention | | | | | |
| Days with asthma symptoms | 42 | −88.33 (107.68) | 57.67 | 21.9, 87.60 | <.0001 |
| Days of quick relief medicine | 41 | −68.25 (131.40) | 24.82 | 1.83, 62.78 | .0002 |
| Days of activity limitation | 40 | −54.39 (100.74) | 4.02 | 0.0, 24.46 | <.0001 |
| Nights of sleep disturbance | 42 | −51.47 (93.81) | 15.33 | 0.0, 30.66 | <.0001 |
| Urgent visits to physician | 40 | −5.11 (7.30) | 0.00 | 0.0, 6.21 | <.0001 |
| Emergency room visits | 42 | −1.83 (4.75) | 0.00 | 0.0, 0.00 | .0024 |
| Hospitalizations | 42 | −0.73 (1.83) | 0.00 | 0.0, 0.00 | .0625 |
| Days of stay in hospital | 42 | −1.46 (5.84) | 0.00 | 0.0, 0.00 | .1563 |
| School days missed | 40 | −5.37 (13.49) | 0.00 | 0.0, 4.55 | .0001 |
| Inhaled steroids | 45 | 34.04 (511.36) | 0.00 | 0.0, 0.0 | .8327 |
| Knowledge caregivers (0–6) | 24 | 7.97 (4.57) | 7.00 | 5.00, 11.00 | <.0001 |
| Knowledge caregivers (7–17) | 26 | 4.62 (4.48) | 3.00 | 2.00, 7.00 | <.0001 |
| Knowledge children (7–17) | 25 | 10.00 (6.99) | 8.00 | 7.00, 11.00 | <.0001 |

SD indicates standard deviation; CI, confidence interval.
School days missed are based on 174 school days in a year.
Health outcome and resource utilization variables are rates based on 365 days a year.
Knowledge scores are out of 60 total points.
Steroid use is beclomethasone dose equivalent.
Differences are based upon the number of participants who completed visit 3.

both groups of caregivers at visit 3 and change in health outcomes and resource utilization was done using Spearman correlation coefficients. Analysis revealed that increased asthma knowledge of all 7- to 17-year-old children at visit 3 had significant correlations with fewer urgent physician visits ($r = 0.37$; $P = .01$) and decreased use of quick relief medicine ($r = 0.30$; $P < .05$) by these children. Knowledge of caregivers of all children 7 to 17 years old was significantly related to caregiver's Emotional Function ($r = 0.44$; $P < .01$), Activity Limitation ($r = 0.55$; $P < .01$) and overall quality of life (QOL; $r = 0.50$; $P < .01$) scores. Relationships between caregivers' or 7- to 17-year-old children's knowledge at visit 3 and change in other health outcomes and resource utilization variables were not statistically significant ($P > .05$).

### Health Outcomes, Resource Utilization, and Inhaled Steroids

Table 3 shows within-group changes in knowledge, health outcomes, health care resource utilization, and use of inhaled corticosteroids (ICS). Both control and intervention group children showed significant reductions from visit 1 to visit 3 in days with asthma symptoms, days of quick relief medicine use, nights of sleep disturbance, urgent visits to physicians, and emergency department visits ($P < .05$).

**TABLE 4.** Health Outcome and Resource Utilization—Children

| | Visit 1 Mean (SD) | Visit 2 Mean (SD) | Visit 3 Mean (SD) |
|---|---|---|---|
| Control | ($n$ = 119) | ($n$ = 84) | ($n$ = 44) |
| Days of asthma symptoms* | 97.8 (109.0) | 53.7 (89.3) | 48.2 (80.0) |
| Days of quick relief medicine | 90.7 (114.8) | 46.6 (90.0) | 41.0 (82.0) |
| Days of activity limitation | 35.3 (71.4) | 17.9 (50.0) | 13.5 (31.4) |
| Nights of sleep disturbance | 62.0 (93.0) | 33.1 (84.3) | 17.1 (54.0) |
| Urgent visits to physician | 6.4 (10.5) | 1.7 (5.0) | 1.3 (2.2) |
| Emergency room visits† | 1.2 (2.8) | 0.37 (1.3) | 0.6 (1.1) |
| Hospitalizations | 0.6 (2.3) | 0.04 (0.4) | 0.1 (0.3) |
| Days of stay in hospital | 2.0 (8.7) | 0.11 (1.1) | 0.4 (2.6) |
| School days missed | 6.4 (12.6) | 1.7 (4.1) | 5.4 (19.8) |
| Intervention | ($n$ = 105) | ($n$ = 67) | ($n$ = 42) |
| Days of asthma symptoms* | 104.5 (113.3) | 39.4 (71.2) | 23.9 (29.6) |
| Days of quick relief medicine | 90.0 (118.2) | 27.7 (50.1) | 26.3 (56.6) |
| Days of activity limitation | 46.2 (94.6) | 15.5 (56.1) | 6.7 (21.1) |
| Nights of sleep disturbance | 64.7 (100.4) | 18.6 (38.8) | 15.2 (32.8) |
| Urgent visits to physician | 6.6 (10.5) | 1.4 (4.0) | 0.8 (1.5) |
| Emergency room visits† | 2.0 (4.2) | 0.6 (3.6) | 0.1 (0.4) |
| Hospitalizations | 0.1 (2.2) | 0.0 (0.2) | 0.1 (0.4) |
| Days of stay in hospital | 2.7 (7.9) | 0.2 (1.7) | 0.6 (1.8) |
| School days missed | 7.9 (18.4) | 1.67 (4.4) | 1.4 (3.2) |

In $\chi^2$ comparison between control and intervention groups:
* $P < .01$.
† $P < .05$.

The control group also demonstrated significant decrease in number of hospitalizations from visit 1 to visit 3 ($P < .05$). Days of activity limitation and number of school days missed decreased significantly between visits in the intervention group alone ($P < .01$).

To assess differences in health outcomes, control and intervention groups were compared using Cochran-Mantel-Haenszel statistic, controlling for baseline scores through a stratified analysis. The intervention group demonstrated significantly greater decrease in days with asthma symptoms (81 vs 51 per year) with a $\chi^2$ of 6.65, $P < .01$ (Table 4). The intervention group also showed significantly greater decrease in the number of annual emergency department visits at year end (1.93 vs 0.62 per year) with a $\chi^2$ of 5.07, $P < .01$ (Table 4). At visit 3, the (beclomethasone equivalent) average daily dose of ICS used by the intervention group was significantly lower (434 $\mu$g) compared with that of the control group (754 $\mu$g) with a $\chi^2$ of 7.31, $P < .01$ (Table 5), although at visit 1 the doses were similar (353 vs 351 $\mu$g).

Differences between groups were not significant for caregivers' QOL scores for all children at visit 3 and change in scores between visits 1 and 3 ($\chi^2$ = 0.036; $P$ = .85) or for children 7 to 17 years old (self assessment) QOL score ($\chi^2$ = 2.51; $P$ = .11). Results for the quality of life subscales for 7- to 17-year-old children were similar, with all $P$ values >.05.

**Program Evaluation**

The intervention group participants filled out a questionnaire to provide feedback about the IMPACT computer program. Results are presented in Table 6. Users found the program easy to use and navigate, interesting, and enjoyable. Teenage children found the program least enjoyable (23%). Although the program was ranked second to physician as a source of obtaining asthma information, >61% participants said that they would use the program again. Program use varied greatly. Based on the percent completion statistic reported by the program it ranged from 40% to 100% among the caregivers of 0- to 6-year-old children completing visit 3 (Table 2), with 50% of users having completed 40% or more of the vignettes. The percent completion report showed that children in 7- to 17-year-old group who completed visit 3 had mastered 48% to 100% of the program, with half of them completing 58% or more of the program. Actual program use was higher than reflected here because of the 6-month start-over feature.

**TABLE 5.** Daily Dose of Inhaled Corticosteroids

| | Visit 1 Mean (SD) | Visit 2 Mean (SD) | Visit 3 Mean (SD) |
|---|---|---|---|
| Control | ($n$ = 119) | ($n$ = 84) | ($n$ = 44) |
| | 350.53 (649.61) | 442.40 (636.46) | 753.88 (706.94) |
| Intervention | ($n$ = 105) | ($n$ = 67) | ($n$ = 42) |
| | 353.09 (615.83) | 390.85 (618.21) | 433.51 (569.13) |

SD indicates standard deviation.
$P < .01$ in $\chi^2$ comparison between control and intervention groups.

**TABLE 6.** Program Evaluation—Percentage of Children and Caregivers Answering "Yes"

| Questions | Children 7–17 Years (%) | Caregivers of Children 7–17 Years (%) | Caregivers of Children 0–6 Years (%) |
|---|---|---|---|
| Easy to use? | 81 | 82 | 89 |
| Interesting? | 31 | 68 | 44 |
| Enjoyable? | 23 | 41 | 33 |
| Easy to navigate? | 65 | 82 | 67 |
| Preferred computer education? | 32 | 43 | 78 |
| Will use again? | 62 | 86 | 67 |

## DISCUSSION

This study shows that supplementing traditional verbal and printed asthma education with the interactive multimedia asthma education program can result in increased asthma knowledge, reduced asthma morbidity, and reduced emergency room costs. The benefits of the program occurred while it was used during waiting times within the customary flow of clinic activities between the recording of vital signs, performance of spirometry, history taking, physical examination, discussions of therapeutic options, and discharge teaching. This approach had the perceived benefit of using patient and family time more efficiently, while not incurring additional staffing overhead.

Knowledge gain was viewed as a primary indicator of program use and effectiveness. The only program utilization variable reported by IMPACT was percent completion. No attempt was made to correlate this statistic with outcomes, because the percent completion statistic would not be expected to adequately reflect knowledge gain. If a child viewed 10 lessons during a 20-minute session and correctly answered questions for only 2 lessons, then the percent completion would be very low. However, this probably underestimates knowledge gain, because for each incorrect answer, a user receives immediate feedback with a restatement of the concept and a rationale for the correct answer. Change in knowledge scores was viewed as a more likely correlate of group differences in outcomes. In addition, the intent-to-treat principle was applied to this study, whereby the analysis accepted program use as an uncontrolled variable.

Length of program use among participants varied and was influenced by travel time to the clinic and duration of the visit. It is important to note that completion of even small portions of the program corresponds with comprehension of critical concepts. If the first 5 of 44 vignettes are completed, a child is exposed to the basic pathophysiology of asthma and the range of symptoms associated with it. If 12 vignettes are completed the concept of control medications is mastered as well. Completing 28 vignettes offers additional information on environmental triggers and how to avoid them.

This study demonstrates that in a busy clinical environment computer-based interactive multimedia education is a feasible adjunct that can be incorporated into the visit without any disruption of the regular visit flow. Our study also demonstrates that traditional care, even with an excellent multidisciplinary asthma team and a structured educational program, can be enhanced by multimedia education. Both control and intervention groups received optimal clinical care, education, and phone support through a team that included a pediatric pulmonologist, a pediatric nurse practitioner, a licensed practical nurse, and a respiratory therapist. Clinical care addressed the major modifiable factors that alter asthma morbidity, including management of environmental triggers, treatment of comorbid conditions, appropriate use of antiinflammatory drugs and bronchodilators, and education for self-management. Within-group changes among control children in this study demonstrate the value of guideline-based clinical care (Tables 3 and 4). One would expect that additional improvements in health status might be difficult to demonstrate in settings where excellent clinical care is provided. However, even greater reductions in the burden of asthma are possible with more effective education for self-management. This is apparent among intervention children after use of IMPACT (Tables 3 and 4).

It is particularly noteworthy that although these substantial improvements occurred among intervention children, their mean ICS dose significantly decreased during the trial compared with the control group (Table 5). This paradoxical finding should be appreciated in context. In the clinical setting where the study was conducted children were often started at higher doses of ICS and over time could usually be managed with lower doses. It is not surprising that children who knew more about asthma and who had better self-management skills eventually required lower ICS doses. Avoidance of environment triggers, better inhalation technique, and closer adherence to therapeutic regimens could all result in a reduction in asthma symptoms, which in turn should encourage a clinician to step down the ICS dose. This is especially true of a child who has learned to communicate their asthma signs and symptoms more precisely. Although the intervention group ended up on a significantly lower mean dose of ICS, it should be noted that the group mean of 434 $\mu$g (beclomethasone equivalent) still falls in the medium dose range. (This equates to 5 puffs twice a day of a beclomethasone chlorofluorocarbons propellant metered dose inhaler or about 1 puff twice a day of the more potent fluticasone 110 $\mu$g metered dose inhaler) The control group mean was in a higher dose range at 754 $\mu$g. This suggests that interactive multimedia education is a potent therapeutic intervention in childhood asthma that has a steroid-sparing effect.

A number of other multimedia educational programs designed as games for pediatric asthma have been designed and tested. At least 4 interactive computer programs using a game format have been developed to teach children about asthma.[17–20] All 4 studies reported a significant increase in asthma-related knowledge; however, efforts to evaluate health outcomes were variable. Two studies showed a reduction in emergency department visits.[17,19] Another[18] showed a lower hospitalization rate and improved functional status. A third study found that health outcomes of the group that played an asthma computer game were not significantly better than the control group children who reviewed written materials.[19] In contrast, IMPACT reduced the burden of asthma in numerous ways and increased knowledge far more effectively than traditional written materials.

As a multimedia educational program, IMPACT departs sharply from the prevailing gaming approach and is unique in several important ways. The effectiveness of IMPACT is likely a result of several factors. Although IMPACT was designed to be understood by young school-age children, the content includes concepts that adult caregivers often do not know. This was evidenced by the increase in knowledge scores and by the verbal comments of many parents who remarked that they had learned a great deal from what seemed at first to be just a program for children. The integration of multimedia design principles, its capability to respond to individual learner needs, and the systematic use of guiding behavioral theory of self-regulation to produce the program resulted in a dramatically more effective program and likely contributed greatly to the success of IMPACT program.

Although this study was not specifically designed to determine the full financial impact of the intervention on asthma care, it is clear that cost savings occurred. This finding is consistent with existing evidence that self-management asthma education is cost-effective.[24] At our institution, the average cost of an emergency department visit for asthma was $470 during the study period. Reduction in emergency room visits in the intervention group at our institution translated into a savings of approximately $907.10 per child (compared with $291.40 for the control group). There was also a significant reduction in the rate of school absences among intervention children (Table 3), a decrease of 5.4 days per child per school year compared with 1.6 days for control children. This represents a direct financial benefit to public schools whose funding is tied to attendance. It is likely that related indirect savings were realized by working parents and employers. Cost savings related to change in medication use was not calculated.

This study demonstrates that effective self-management education is a potent intervention for reducing asthma morbidity, yet it might be argued that the financial burden of such an intervention would fall on physicians in primary care who are not reimbursed for the cost of education. Loss of revenue resulting from reduced office sick visits might also be a concern. These concerns ignore the fact that without appropriate care, children with poorly controlled asthma are more likely to end up in hospital or specialty settings. Scheduling more regular office visits would reduce the need for urgent care by increasing opportunities to reassess and monitor the child, adjust therapy, and improve self-management. This strategy that is advocated by expert guidelines would actually increase reimbursement for primary care services, while lowering the overall cost of asthma to the health system. Another concern is the cost and difficulty of using computers in busy practices. In clinics where computer terminals with Internet access are not available, use of portable, wireless devices with earphones would be more practical and would have the added advantage of engaging the patient in useful activities from check-in until completion of the visit.

This study addressed the basic question of whether the tutorial content and interactive design of IMPACT delivered within the context of an office visit would contribute to improved asthma outcomes. Although this study did not evaluate each Internet-enabled program feature, such as symptom and medication-use reporting, the tutorials were coordinated and reported by a secure server over the Internet. This fact has tremendous bearing on the eventual cost, accessibility, and sustainability of this educational intervention. A similar program using a local client server would not provide the same capabilities.

Although this study focused on program use in a specialty clinic setting, IMPACT was designed to be used by the individual child at multiple locations. Future studies should evaluate the effectiveness of this approach at home, school, primary care, and community settings, such as libraries, where most children live with asthma day-to-day. Greater access to Web-enabled multimedia programs of this type could extend substantial benefits to larger populations of children who have asthma and possibly other disease processes. Health policy changes are needed to ensure adequate funding for Web-enabled multimedia patient education.[16] Several advantages are afforded by this approach. Barriers to effective patient education can be removed by strategic use of the Internet. Resources for software design and maintenance can be centrally pooled in a Web-enabled model with the effect of lowering cost to the end user, enhancing program quality, facilitating automatic content updates, and promoting easy and widespread access. These factors increase the likelihood that economically disadvantaged and at-risk populations will benefit.[25]

Our study has some limitations. The symptom history and resource utilization data were based on self-report of children and caregivers. The accuracy of their reports could not be independently validated. Because the study was conducted in 1 pediatric specialty clinic serving primarily rural children, results might not apply to other populations with different demographics. The recall period for the quality of life instrument was 1 week.[22] Brief recall interval might not adequately reflect the variable

pattern of asthma over several months. At the time of the study no suitable, validated knowledge instrument existed. The 60-item knowledge instrument used in our study has not been subjected to rigorous psychometric analysis. Also, it would have been very useful to know how many and which particular lessons were viewed by each IMPACT program user, including the ones not mastered. Other useful data would include the number of vignettes accessed and the frequency of access. We would like to point out that as expected, percentage of 7- to 17-year-old children who said that they enjoyed the program is much lower than the caregivers of both younger and older children.[26] This confirms that the current version of the IMPACT program is suitable for children under 12 years and if it were to be used by older children, it will require significant design changes that will appeal to older children.

Our findings of increased asthma knowledge, decreased morbidity, and lowered use of emergency services have direct implications for health care providers and insurance companies. Physicians should consider incorporating interactive multimedia education into routine clinical practice. Health maintenance organizations and third-party payers should finance effective education for self-management so that patients and caregivers can achieve better control of asthma, and health systems can conserve resources. A specific *Current Procedural Terminology* code for individual education should be adopted to facilitate reimbursement and to further encourage clinicians to prescribe self-management education as a therapeutic intervention in the care of children with asthma.

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